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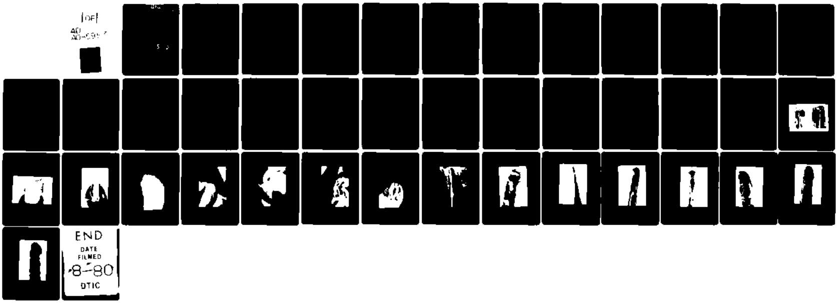

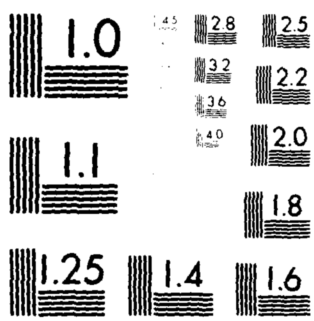

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An *in vitro* technique was developed to evaluate the ability of various filling techniques to fill an artificial standard canal system. No significant difference was noted in volume changes over a two-week period between lateral condensation, vertical (warm) condensation or compaction (mechanical) condensation. The ability of the techniques to replicate the canal was statistically analyzed. It was found that the compaction technique was significantly better than the lateral technique ($p<0.01$), and the vertical technique was significantly better than compaction technique ($p<0.001$). The compaction technique was significantly the fastest.

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Comparison of Gutta Percha Filling Techniques. Part 1:

Compaction (Mechanical), Vertical (Warm), and Lateral Condensation Techniques

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Abstract

An *in vitro* technique was developed to evaluate the ability of various filling techniques to fill an artificial standard canal system. No significant difference was noted in volume changes over a two-week period between lateral condensation, vertical (warm) condensation or compaction (mechanical) condensation. The ability of the techniques to replicate the canal was statistically analyzed. It was found that the compaction technique was significantly better than the lateral technique ($p<0.01$), and the vertical technique was significantly better than compaction technique ($p<0.001$). The compaction technique was significantly the fastest.

Introduction

Ultimately, the goal in any conservative root canal therapy is the complete obturation of the root canal system.[1,2] Studies[3,4] have shown that the morphologic configuration of a root canal is not merely a single tubular space within the root. The presence of accessory canals, lateral canals, anastomoses, and fin-shaped extensions give the canal spaces a complex configuration. With presently available materials and techniques, the complete obturation of all canal systems is impossible.[5,6] Clinicians should still strive to obturate the canal as completely as possible.

The gutta percha filling is preferred by most endodontists as a filling material because of its permanency and capacity to be condensed against the irregularly shaped walls of the canals.[7,8,9] There are many different techniques of filling root canals with gutta percha[8,9,10], unfortunately, each proponent usually bases the success of his technique on radiographic or clinical evidence alone.

Qualitative evaluations of gutta percha fillings have been made on extracted teeth.[6,11,12] The observations of the gutta percha fillings were made after dissolving away the tooth structure with twenty percent nitric acid. A major weakness of these studies was that the nitric acid could possibly affect the sealer and thus distort the fillings' appearance. Also, the reference for comparison of the fillings was a silicone impression of a different tooth.

The use of an artificial root canal would eliminate the need for exposure of the gutta percha filling to reagents such as nitric acid. It would provide a standardized reference for the evaluation of different fillings with regards to procedure time and replication properties.

Recently, a compaction gutta percha technique[18,19] has gained the attention of the endodontic community. Initial response to the technique appears to provide an uniform gutta percha filling in a significantly more efficient manner.

The purpose of this study is to present a method of fabricating an artificial canal and to compare the replication abilities, volumetric changes, and simulated procedure time of three gutta percha filling techniques: the lateral condensation, warm gutta percha (vertical condensation), and the compaction (mechanical) gutta percha techniques.

Material and Methods

Fabrication of the Standardized Root Canal Filling

An extracted maxillary lateral incisor was prepared endodontically and filed to a size #60 file. The tooth was soaked in a 5% sodium hypochlorite solution for 2 days,[12] washed in tap water and then placed in 70% isopropyl alcohol for 1 day.[13] The tooth was air dried and filled with a casting resin[+] under 21 psi vacuum.[12] The resin was allowed to polymerize for 24 hours and then the tooth was placed in 20% nitric acid until it was completely dissolved, liberating the resin form. The resin "impression" was removed from the nitric acid, washed, invested, and cast in gold.

Fabrication of the Artificial Root Canal

A resin mold of the gold casting was fabricated. Casting resin was mixed and poured into a small box-shaped container. The gold casting was submerged horizontally into the resin at a depth of approximately one-half the dimension of the casting. The resin was allowed to polymerize. After polymerizing, four hemi-spherical notches were made with a #4 round bur to form reference points for repositioning the halves of the mold. Separating medium (petroleum jelly) was placed over the polymerized resin. A second pour of casting resin was placed over the exposed half of the gold casting. When the resin had polymerized, the two halves of the mold were separated and the gold root canal removed. The two halves of the resin mold were then invested and casted in gold (Fig 1A). One-eighth inch portions of the sprue on the outer surface of the mold were left on the casting for retention of a resin buildup. This added more bulk for convenience in handling of the mold. Once the resin buildup was added to the mold, the halves of the gold mold (Fig 1B) were re-adapted and held in place with a clamp (Fig 1C), thus forming an artificial root canal.

A silicone impression of the artificial root canal was taken. The silicone impression became the standard when evaluating the gutta percha fillings (Fig 2).

Root Canal Filling

A stop watch was used to record the time needed for each filling procedure. A total of sixteen fillings were made using each fill technique. For each technique, the artificial canal was filled with gutta percha (Fig 3A) and the excess removed with an heated scalpel so that the coronal end was flush with the surface of the model (Fig 3B-D). The elapsed time was recorded. The halves of the mold were separated and the gutta percha filling removed from the artificial canal (Fig 4). A black and white photograph of each filling was made at 25X.

Volumetric Study

The hydrostatic volumetric measurements were performed in the following manner: The fillings were weighed in air and alcohol using a balance++ to an accuracy of 0.01 mg. and recorded. Three readings were taken of each weighing. In preliminary work, water was used as the liquid media for volumetric studies. However, it was found that the specific gravity and water tension had a dampening effect in the weighing process. The use of isopropyl alcohol avoided this effect. A small beaker of alcohol was placed so that the stirrup of the balance was submerged in alcohol. The scale was recalibrated to zero. The gutta percha was then placed on the stirrup and re-weighed under alcohol. Then the gutta percha filling was placed in an incubator at 37°C for 2 weeks. At this time a second weighing of the filling was made in air and under alcohol. At 3 weeks another 25X photomicrograph was made of each filling.

Evaluation

Evaluation was performed by three evaluators who viewed the gutta percha fillings at 25X under a stereoscopic microscope. Evaluation of the replication abilities of the three techniques were done 3 weeks after the fillings were made. Using the silicone impression as a standard reference, each evaluator classified the fillings into one of four categories: (1) Poor: no apical replication, many wrinkles and folds, no fins; (2) Acceptable: some apical replication, some wrinkles and folds, minimal fins; (3) Good: good apical replication, few wrinkles and folds, fins; (4)

Excellent: excellent apical replication; no wrinkles and folds, fins. The results were compared and the ratings of the techniques were compared by contingency tables.

In the volumetric study, the difference in weight between the gutta percha in air and in water is equivalent to the volume of the gutta percha. The volume of an object submerged in water is equivalent to the volume of water it displaces. Archimedes' principle describes the relationship between displaced liquid and buoyancy as "An immersed body is buoyed up by a force equal to the weight of the fluid it displaces." The negative change in weight of the gutta percha filling when submerged in water is the buoyant force. The buoyant force remains constant regardless of depth. Since the weight of the object when submerged in water is equivalent to the water displaced, the volume of water displaced is the volume of the object (gutta percha filling).[14] Since alcohol, not water, was used, a conversion factor was included to account for its specific gravity. Changes in volume from weighings taken 2 weeks later were recorded and percent volume change determined.

The time required for the performance of each technique was recorded in decimal minutes.

Results

Weight and Volume Changes

Descriptive statistics of the technique specimens are given in Table 1. Average weights in air was 77.24 mg. for laterally condensed fillings, 80.00 mg. for vertically condensed fillings, and 90.65 mg. for compaction condensed fillings. The weight changes in air over 2 weeks are insignificant, although specimens produced by lateral condensation increased an average of 0.70 mg., vertical condensation specimens an average of 0.57 mg. and compaction specimens decreased an average of 0.29 mg. The lateral condensation technique showed an average volume increase of 1.13% after 2 weeks. The vertically condensed fillings showed an average volume shrinkage of 0.45%, and the compaction condensed fillings showed a volume shrinkage of 0.62%.

The average percentage volume changes (Δ% vol.) were derived by first making pair-wise comparisons for each individual filling at the time of fill and then after 2 weeks. The changes for all fillings in a group were then averaged to get the average percentage volume change for each group with its standard deviation.[20]

The average time required for fillings was 7.99 min. (±1.28) for vertical condensation, 5.62 min. (±1.10) for lateral condensation, and 1.31 min. (±0.17) for compaction.

<u>Replication Abilities</u>

The qualitative evaluation for the various techniques is summarized in Table 2. The evaluators were unanimous in their assignment of categories in 72% of all cases. The rest were decided by majority vote. As can be seen from Table 2, the vertical condensation technique (Fig 4B) was judged significantly better than lateral condensation (Fig 5,6) or compaction technique (Fig 7) in its ability to replicate the test canal. The compaction technique was better than the lateral condensation which produced fillings consistently judged as poor or barely acceptable by all investigators. For statistical purposes, the data were further divided into Poor vs Acceptable-Excellent, and Poor-Acceptable vs Good-Excellent categories. Table 3 shows that vertical condensation and compaction were judged significantly better than lateral condensation at the $p<.0001$ level. Table 4 shows that the compaction technique produced significantly more fillings in the Good-Excellent category than the lateral condensation technique ($p<0.01$). Table 5 shows that the vertical condensation technique produced significantly more fillings in the Good-Excellent category than the compaction technique ($p<0.001$).

In a comparison between the immediate post-fill and 3-week post-fill 25X microphotographs, no significant differences were noted except for slight separation of the points seen with the lateral condensation (Fig 6).

Discussion

The Artificial Canal

In the past, extracted teeth have generally been used as a means of observing the replication abilities of gutta percha. Using extracted teeth did not prove feasible for studying the quantitative volumetric changes of various types of gutta percha fillings.[15] However, the use of an artificial root canal proved to have certain advantages.

1. An artificial canal provided a standardized reference to compare the different root canal filling techniques' ability to produce an impression of a root canal.

2. An artificial root canal provided a standardized reference to compare the time necessary to fill the same root canal using various techniques.

3. A standardized artificial canal avoided the problem of the

gutta percha filling being affected by reagents during the decalcification stages of the real tooth.

4. A standardized artificial root canal enabled immediate observation and measurement of gutta percha filling after condensation so that volumetric measurements could be taken postoperatively. Decalcification may take up to 10 days, preventing any volumetric evaluations.

5. A standardized artificial root canal enabled gutta percha fillings to be approximately the same size. Thus, if shrinkage varied with the amount of surface area and amount of bulk of the gutta percha filling, then this variable could be kept relatively constant.

Weight and Volume Changes

The higher average weight of the vertically condensed fillings compared to the laterally condensed fillings (80.00 mg. vs 77.24 mg.) does indicate an ability to get more gutta percha into the canal system using the vertical warm technique. Unfortunately, the same cannot be said for the higher average weight using the compaction technique since gold particles were removed from the canal wall and incorporated into the fillings (Fig 7A).

The small variation in weighings in air of the same fillings taken 2 weeks apart (Table 1) were insignificant in relation to the overall results. This variation may be explained by calibration error, voltage variation, or barometric pressure changes. Whatever the cause, since volumetric changes were calibrated on the air and fluid weighings taken on the same day, this error should only relate to the air weighings taken 2 weeks apart. Volumetric determinations are independent of this variation of weight measurements.

In this study, hydrostatic volumetric measurements did not show a statistically significant difference between fillings of the three techniques. The only significant change occurring over 2 weeks not explained by possible calibration error, voltage variance or barometric pressure change was the 1.13% increase in average percent volume change (Δ% vol.) shown by the lateral condensation group. This probably relates to the observation that with time, accessory cones had a tendency to separate slightly from the master cone (Fig 6A,B). This was more evident clinically than photographically. These minute separations may have formed air pockets which were recorded as slight size increases when measured by submersion.

Warm gutta percha has been shown to expand 1-2% when subjected to heat.[15] In this study, the warm gutta percha techniques did not show shrinkage of this extent (only 0.45% for vertical condensation and 0.62% for compaction). This may indicate that here a significant portion of the cooling and shrinkage occurred immediately following filling prior to weighing. How shrinkage disrupts the effectiveness of the seal is being studied.

Replication Abilities

In this study the vertical condensation technique best replicated the canal system (Tables 3-5). The fillings were homogenous and the surface texture was smooth (Fig 4) like the silicone control (Fig 2). The lateral condensation technique, at times, produced a smoother gutta percha filling than expected (Fig 5). Some coalescence of the master and accessory cones was observed without the aid of any sealer. However, after 3 weeks there was a tendency of accessory cones to separate much on the order noted by Brayton et al. (Fig 6). Also, the replication of the apical 2-3 mm was not as good as those produced by the vertical condensation or compaction techniques.

Larder and Brayton[11] compared the replication abilities of lateral condensation and warm gutta percha (vertical condensation) with sealer. He found no significant difference between the two techniques. In this study, a definite difference was noted but no sealer was used.

The compaction technique produced a filling which replicated the canal better than a filling produced by the lateral condensation technique, but poorer than a filling produced by the vertical condensation technique (Table 3-5). The overall surface of the filling was not homogenous; many horizontal interfaces of gutta percha were characteristics of this filling. Because of the multi-interfaces, a roughened appearance of the filling surface was evident. Also, evidence of incomplete heat compaction in the form of a spiral-like apical portion was a common finding (Fig 7B). This observation is consistent with Foster.[17] Inspite of this finding, the replication of the apical 2-3 mm and the margin (interface of the two halves of the mold) of the canal were superior to the lateral condensation technique (Fig 7C).

The compaction gutta percha technique was done last because of the possibility of the compactor cutting the canal walls slightly. It was also done after all chloropercha techniques to be reported in Part 2 of this study were completed. This did occur producing an easily distinguishable filling with particles of gold filings being incorporated into the fillings.

As noted, this was probably responsible for the significantly higher weight and volume measurements of the fillings produced by the compaction technique. The presence of filings in the filling indicate that the compactor may have similar effects on dentin. Gross observations of the compaction technique on simulated clear acrylic canals appeared to show better adaptation to the irregular configurations of various types of canals[18] than generally noted here. This may be related to several considerations. First, in this study, the fillings were evaluated at 25X; second, it is possible that the heat of compaction is dissipated more rapidly through the gold than acrylic, not allowing the gutta percha to soften as well; third, it is possible the instrument was inhibited or slowed more by bearing on gold rather than acrylic. How these differences in materials relate to the compactor acting next to dentin was not studied.

Time:

The obturation of the artificial canal using the compaction technique proved much more rapid (1.3 min.) than either lateral condensation (5.62 min.) or vertical condensation techniques (7.99 min.). If operator expertise was the explanation for these results, then lateral condensation probably should have been the fastest. In actual clinical practice, the compaction technique may prove to be fastest. Not only may the obturation time be shorter, but the recommended minimal taper in canal preparation may result in less time being needed for canal preparation.[19]

Caution should be used when applying the findings of this study to the clinical situation. If the replication properties and time factors are significantly different with one technique as opposed to another, then the findings would strongly suggest that analogous results may occur *in vivo*. To what extent similar findings *in vivo* would occur is unknown. The procedure for filling canals on a bench will not correspond completely to the technique used clinically. Using a model system without the compressibility of dentin does limit how applicable the results are to the clinical situation. However, if a given technique produces fillings *in vitro* that have superior characteristics, then the technique should deserve serious considerations for its use *in vivo*.

Conclusions

A compaction gutta percha technique has recently gained the attention of the endodontic community. Initial response to the technique has been favorable. Using an artificial root canal, the replication abilities, volumetric changes and simulated procedure time of this technique, as well as the vertical condensation and lateral condensation techniques, were studied in 48 root canal fillings. Volumetric studies showed no significant differences between the three techniques, although vertical condensation consistently placed a larger volume of gutta percha into the space than lateral condensation.

The replication abilities of the compaction gutta percha technique were significantly superior to the lateral condensation technique but were inferior to the vertical condensation technique. The difference in filling time indicated that the compaction technique may be clinically more rapid than vertical or lateral condensation. If the compaction technique proves as simple *in vivo* as *in vitro*, it may be an excellent alternative endodontic procedure.

+Duralay-Reliance Dental Mfg Co., Worth, Illinois

++Cahn-Model 4100 Electrobalance-Cahn/Ventron Corp., Paramount, CA

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Table 1. Weighing changes in air and alcohol over a two-week period with percent volume changes (Δ% vol.) and average time for filling for each group.

	Original Ave. Wt. on Air	Original Ave. Wt. in Alcohol	At 2 Week Ave. Wt. in Air	At 2 Week Ave. Wt. in Alcohol	Δ% Vol.	Time
Lateral	77.242 ±1.536	54.444 ±1.093	77.950 ±1.485	54.859 ±1.128	+1.132 ±0.606	5.616 ±1.106
Vertical	80.002 ±2.154	55.786 ±1.839	80.573 ±2.011	56.409 ±1.896	-0.448 ±1.148	7.989 ±1.278
Compaction	90.648 ±4.053	63.996 ±3.773	90.362 ±3.989	62.953 ±3.061	-0.666 ±1.516	1.313 ±0.168

Table 2. Common rank of each filling. Evaluated separately by each evaluator. Seventy-two percent were total agreement and the rest were placed by majority agreement.

	1-Poor	2-Acceptable	3-Good	4-Excellent
Lateral	11	5		
Vertical	1		9	6
Compaction		10	6	

1-Poor: no apical replication, many wrinkles and folds, no fins.
2-Acceptable: some apical replication, some wrinkles and folds, minimal fins.
3-Good: good apical replication, few wrinkles and folds, fins.
4-Excellent: excellent apical replication, no wrinkles and folds, fins.

Table 3. Rankings combined in Poor and Acceptable to Excellent Groups for all three techniques.

	Poor	Accept.-Excellent
Lateral	11	5
Vertical	1	15
Compaction	0	16

df = 2 $x^2=24.666$ $p<0.0001$

Table 4. Rankings combined into Poor to Acceptable and Good to Excellent Groups to compare lateral condensation and compaction.

	Poor-Accept.	Good-Excellent
Lateral	16	0
Compaction	10	6

df = 1 x^2=7.385 $p<0.01$

Table 5. Rankings combined into Poor to Acceptable and Good to Excellent Groups in order to compare compaction and vertical condensation.

	Poor-Accept.	Good-Excellent
Compaction	10	6
Vertical	1	15

df = 1 $x^2=11.22$ $p<0.001$

Legend

Figure 1A. Two halves of the root canal mold. Four hemi-spherical notches (left half) and their positive impression (right half) served as reference points for repositioning the halves of the mold. Canal length: 15 mm.

Figure 1B. Two halves of mold positioned to form artificial root canal. Resin buildup placed on outer surface for convenience in handling. Vertical indentations on resin produced by clamp during setting of resin served as reference for placing clamp during filling procedures.

Figure 1C. Two halves of mold held in place by clamp, thus forming an artificial root canal.

Figure 2. Silicone impression of artificial root canal (25X).

Figure 3A. Artificial canal being filled with gutta percha (lateral condensation).

Figure 3B. Excess gutta percha (lateral condensation) being removed with heated scalpel.

Figure 3C. Excess gutta percha filling (vertical condensation) being removed with heated scalpel.

Figure 3D. Gutta percha filling flush with coronal surface of mold.

Figure 4A. Gutta percha filling (vertical condensation) just prior to removal from mold (10X).

Figure 4B. Vertical condensation filling. The filling is homogenous and the surface texture smooth. Replication of the apical portion of the canal was judged excellent (25X).

Figure 5. One of the best of the lateral condensation fillings. Some coalescence of the master point and accessory cones can be observed. Incomplete adaptation to the apical portion of the test canal was invariably noted (10X).

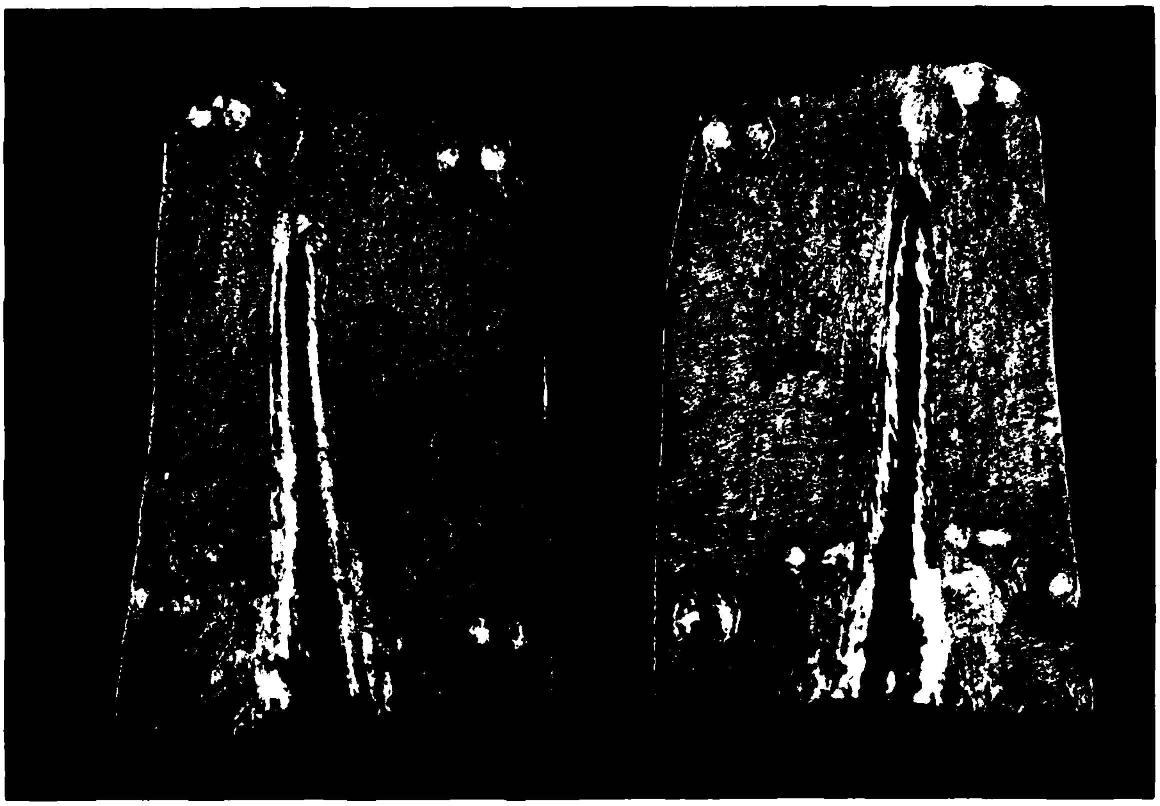
Figure 6A. Lateral condensation filling prior to removal from mold showing some coalescence of master and accessory points (25X).

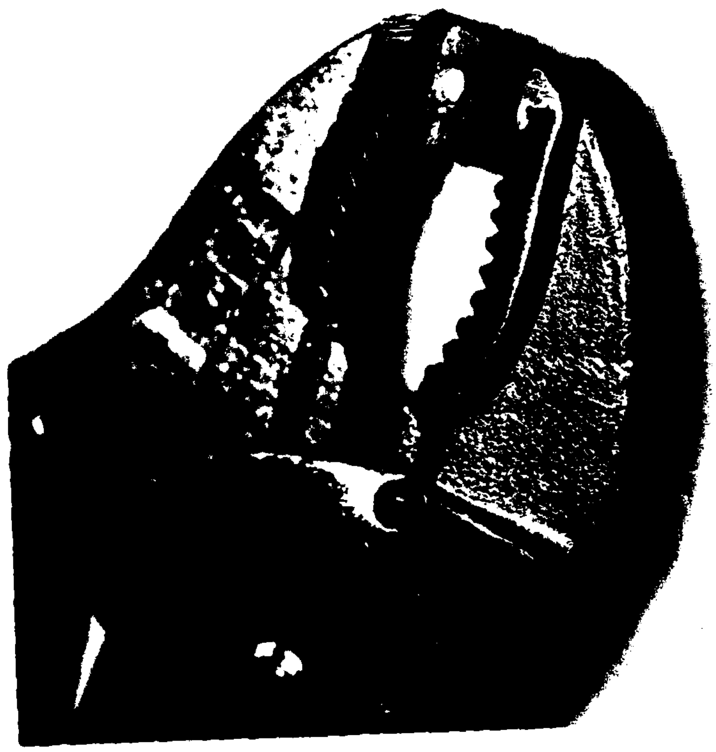
Figure 6B. Same lateral condensation filling 3 weeks later showing a slight tendency of accessory cones to separate (25X).

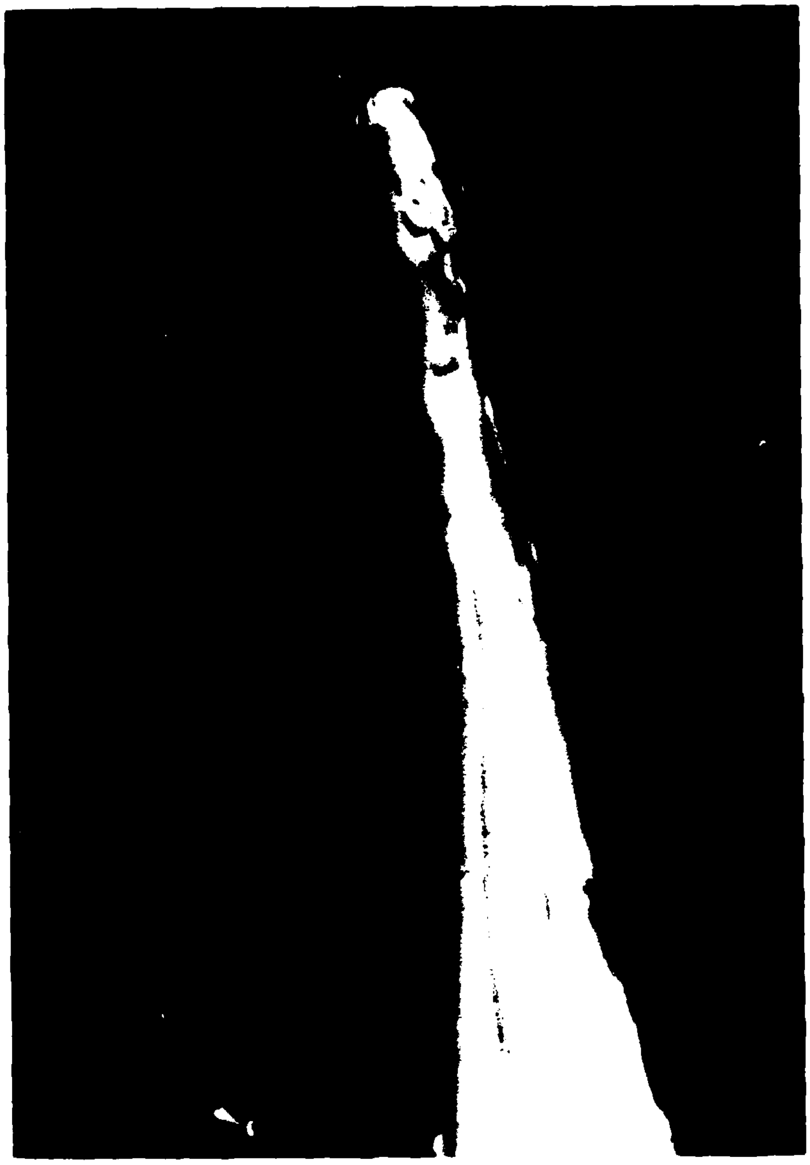
Figure 7A. Compaction condensation filling. Gold filings seen in majority of cases. Overall surface is not homogenous. Many horizontal interfaces of gutta percha were characteristic of this filling. Replication of the apical 2-3 mm. and mold interface superior to lateral condensation (25X).

Figure 7B. Compaction condensation filling showing incomplete heat compaction resulting in a spiral-like apical portion (25X).

Figure 7C. Compaction condensation filling showing example of best replication achieved by this technique (25X).







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